Multiscale Simulations and Experiments of the Role of Dislocation-Twin and Twin-Twin Interactions on the Hardening Response of Magnesium

Thursday, September 17, 2015
4:00 p.m. | 202 Reed McDonald Building

Abstract

With increasing demand to reduce carbon dioxide emission, recent efforts are directed towards reducing the structural weight of fossil fuel powered vehicles to increase their fuel efficiency. As the lightest structural metal (one-third lighter than aluminum), magnesium (Mg) and its alloys have been attracting a lot of attention in recent years for their potential use in automotive, aerospace and defense applications. However, at present, the wide use of Mg alloys as a structural material is still challenging due to their poor room temperature formability. Owing to its hexagonal closed packed (HCP) structure and low crystal symmetry, complex deformation mechanisms, including dislocation-slip and twinning are typically reported. As a result, the mechanical behavior of Mg metals displays strong anisotropy and strong orientation dependence. Thus, identifying the fundamental aspects of plastic deformation in this class of metals is necessary to help improve their performance through alloying and microstructure design.

In this talk we report room temperature microscale experiments on the transformation of deformation mechanisms in Mg single crystals as a function of crystal size. An anomalous strain hardening response is observed and correlated to a size dependent transition from plasticity dominated by single twin propagation followed by massive dislocation slip, to twintwin interactions dominated response, and finally the recovery of bulk like response. To shed light on this, we have developed a hierarchical multiscale simulations method to investigate dislocation and twinning mediated plasticity in Mg. Molecular dynamics simulations are performed to identify the formation and slip of pyramidal dislocations, dislocation junctions, and dislocation twin boundary interactions. These information are subsequently used to develop a new implementation of a twin boundaries (TBs) into the framework of three-dimensional discrete dislocation dynamics (DDD) to simulate the collective evolution of dislocation and their interactions with TBs in Mg single and polycrystals. Through these simulations we report on the effect of crystal size and orientation on the deformation of Mg microcrystals. We also report on the influence of dislocation interactions with TB and the glide of TB dislocations on the evolution and propagation of TBs.

Dr. El-Awady is currently an Assistant Professor of Mechanical Engineering at Johns Hopkins University (JHU) since 2010. Dr. El Awady received his B.S. in 2001 and M.S. in 2003, with a major in Aeronautic and Astronautic Engineering from Cairo University, Egypt, and his Ph.D. in Aerospace Engineering from the University of California, Los Angles (UCLA) in 2008. Prior to joining JHU, Dr. El-Awady was a visiting scientist at the Wright Patterson Air Force Research Laboratory in Dayton Ohio. Dr. El-Awady’s research group focuses on developing multiscale simulation techniques, and microscale experiments to predict the underlying deformation, damage, and failure mechanisms in materials. Prof.El-Awady is the recipient of multiple awards including: the DARPA Young Investigator Program in 2012, the ASME Orr Early Career Award in 2014, and the National Science Foundation CAREER Award in 2015.

Refreshments will be served at 3:45 p.m. | Hosted by Amine Benzeaga